T-SERIES POSITIONING PRODUCTS

USER'S MANUAL

Covers models T-CD, T-HLA, T-LA, T-LS, T-LLS, T-MM, T-NM
Firmware Versions 2.00 through 2.99

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Visit www.zaber.com for more recent updates.

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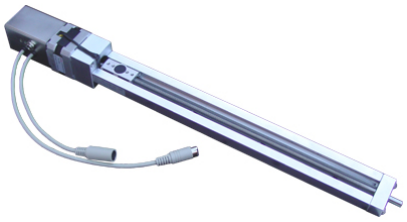
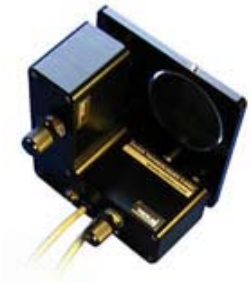
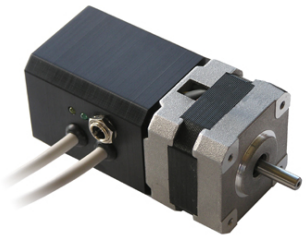
1. ZABER T-SERIES POSITIONING PRODUCTS

T-LA Series – Linear Actuators	T-HLA Series – Heavy Duty Linear Actuators
	
T-LS Series – Linear Stages	T-LLS Series – Long Travel Linear Slides
	
T-MM Series – Motorized Mirror Mounts	T-NM Series – Steppers with built in Controllers
	
T-CON Series – Stand-alone Controller	T-CD Series – Chopper Drive Stepper Controller
	

Product Updates: If you would like to receive our quarterly email newsletter with product updates and promotions, please sign up at http://www.zaber.com (news section).

1.1. *Series Specifications*

Power Supply: 12V nominal (12V to 16V acceptable) DC unregulated supply on 2.1 mm, center positive power connector. Note that voltage will affect available thrust.

Communications: RS232, 9600 baud, no parity, one stop bit on 6-pin mini din cable (PS/2) male towards the computer, female towards the next unit

1.2. *Device Specifications*

Part #	Range	Resolution	Repeatability	Accuracy	Backlash
T-LS13	13 mm	0.1 um	<0.4 um	<12 um	<4 um
T-LA28A T-HLA28 T-LS28	28 mm	0.1 um	<0.4 um	<12 um	<4 um
T-LA60A	60 mm	0.1 um	<0.4 um	<16 um	<4 um
T-LS80	80 mm	0.1 um	<0.4 um	<16 um	<4 um
T-LLS105	105 mm	0.16 um	<0.5 um	<16 um	<16 um
T-LLS260	260 mm	0.16 um	<0.5 um	<20 um	<16 um
T-MM2	-5.5° to +5.0°	1.5 mrad	<7 urad	<180 urad	<15 urad
T-NM	N/A	0.028°	<0.1°	<1.0°	N/A

Part #	Stall Load *	Max Speed *	Current Draw	Mounting Interface	Manual Control
T-LS13 T-LS28 T-LS80	60 N	4 mm/s	320 mA	¼”-20 or M6 holes	Yes
T-LA28A T-LA60A	40 N	4 mm/s	320 mA	3/8-32 threaded shank	Yes
T-HLA28	60 N	4 mm/s	500 mA	3/8-32 threaded shank	Yes
T-LLS105 T-LLS260	93 N	6 mm/s	800 mA	#5-40 holes	Yes
T-MM2	40 N	60 mrad/s	600 mA	¼”-20 (M6 adapter available)	Yes
T-NM	2100 g-cm	180 rpm	900 mA	M3 holes, 5mm shaft	Yes
T-XXXX-S	All part numbers are available with the “-S” suffix. These parts are identical to the standard part except that they have no manual control.				No

* Thrust is a function of speed. These values cannot both be achieved simultaneously (i.e. at maximum speed, the unit will stall at a load of about 1/3 the indicated stall load).

2. FIRMWARE VERSION INFORMATION

The version of firmware installed on any Zaber T-Series device can be determined by issuing command #51.
A 3 digit number will be returned. Assume 2 decimal places (ex a reply of 293 indicates firmware version 2.93). This user's manual applies only to devices with firmware version 2.00 through 2.99.

Newer firmware versions may be available. Due to the addition of new features, newer versions of firmware may not be 100% compatible with older versions. For more information on firmware versions that may have been released since the printing of this manual, please check the support section of Zaber's website where user's manuals for all versions of firmware are posted for download.

You may also wish to read the document "Zaber T-Series Firmware History and Migration" which should be posted on Zaber's website as well and updated regularly. This document specifies what version of firmware currently ships standard on each device, as well as outlining the changes that have taken place from one firmware version to the next and indicating what options are available if you wish to upgrade or downgrade the firmware on your devices.

3. CAUTION

Zaber's positioning devices are precision instruments and must be handled with care. In particular, leadscrews must be treated with care. Axial loads in excess of the stall load, axial and radial impact, dust and other contaminants and damage to the leadscrew thread will reduce the performance of the unit below stated specifications. Performance depends very much on the condition of the leadscrew. On actuators such as the T-LA and T-HLA series, the plunger should always be left in the fully retracted position (home) when not in use. This protects the leadscrew from the environment. The leadscrew may be cleaned periodically for best results. To clean the screw, first use methanol to dissolve old grease and contaminants. There are plastic components that may be damaged by some strong solvents. A small amount of silicon based grease should be applied to reduce friction, backlash and sticktion. For vacuum compatible products, we recommend NyeTorr 5300 silicon based vacuum grease available from www.nyelubricants.com.

4. INITIAL SETUP AND TESTING

If you are unfamiliar with T-series devices, you may wish to perform a few simple steps to familiarize yourself with their operation. First you will need a power supply. If you ordered one with your device you shouldn't have any problems. If not, you will require a power supply with output voltage between 12 and 16V. The power input accepts a standard 2.1mm center positive connector. Most 12V AC to DC adapters output around 16V under light current draw, dropping to 12V at their rated current. Some may output higher voltages and will not be suitable. The chosen power supply must be also be rated to handle the maximum total current draw of the devices connected to it. For example, if you have two T-LA units chained together with a single power supply, you will need at least 640 mA (320 mA per actuator, x 2). When powering long chains of devices, we recommend connecting a power supply to at least every 2nd device in the chain to reduce the current through the data cables.

When connecting several units in a daisy chain, first connect the units to one another. Then only apply power when all of the units are connected properly.

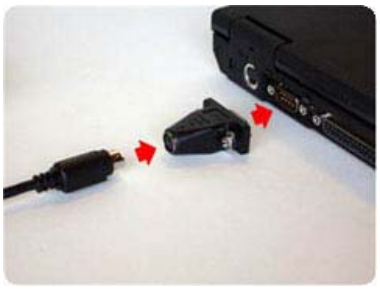
Once you have a working power supply, you can test the operation of your device. If you have a device with manual adjustment, turn the potentiometer counterclockwise to home the device. When operating manually, you must home the device every time you disconnect or turn off the power. You will not be able to achieve the maximum travel until you have homed the device. After the unit retracts completely it will stop automatically and you can turn the potentiometer clockwise to extend the device.

If you have a T-xxxx-S model you cannot control the unit manually. Instead you must install the device on a computer. See the next section for information on how to do this.

5. INSTALLATION

5.1. *Connection to a Computer*

Connecting Zaber devices to a computer is a very simple process:

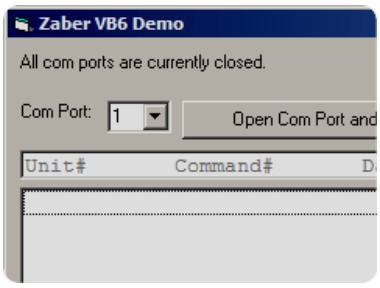


Step 1. Plug the Mini-DIN to D-Sub serial adapter into your computer's serial port and plug the device's data cable into the adapter. You may need to use a cable extension to reach your computer.

There is no need to power-down or reboot the computer.

USB-to-RS232 converters are available if you have no RS232 serial port.

Step 2. Connect the power plug of your power supply (2.1mm center positive) to the power connector of the device. The green LED should light indicating the unit has power.



Step 3. Install a demo program from the included CD, or download one from the support section of our website http://www.zaber.com. Follow the instructions in the readme file to install and run the program.

As a simple first test, try entering these instructions:

Unit	Cmd	Data	Description
0	2	0	Renumber
1	1	0	Home

Additional Devices. Additional units can simply be daisy-chained to the first. For long chains, a power supply should be connected at every 3rd unit. A renumber command needs to be issued after a new unit is connected before it can be controlled independently from the demo program.

5.2. *Linear Actuator Products (T-LA and T-HLA series)*

When mounting linear actuators, care must be taken not to over-constrain the leadscrew. At the point of contact of the leadscrew with the object to be moved there are 6 degrees of freedom which can be constrained: translation along xyz axes and rotation about those axes. The load should constrain only the axial translation of the leadscrew. The simplest way to achieve this is to have the lead screw press against a flat surface perpendicular to the axis of the leadscrew. Any further constraint (such as rigidly fixing the leadscrew to the load) may result in an over-constrained condition that will reduce thrust or cause the leadscrew to bind.

5.3. *Vacuum Compatible Devices*

Zaber's vacuum compatible devices (devices with the suffix "-V" in the part number are identical in appearance and function to their non-vacuum compatible counterparts with the following exceptions:

Lubrication: All lubricated interfaces (motor bearings, leadscrews, leadnuts, etc) are cleaned and regreased using a vacuum compatible lubricating gel (NyeTorr 5300, vapor pressure ~5x10-9 Torr at 25°C). We make every effort to remove all trace of the original greases (some components arrive from our manufacturers pre-assembled, and pre-greased) but for best results we recommend degassing the units before use in the final application.

Power: No power connectors are provided on vacuum compatible devices. Instead, the power must be supplied through the data cable lines. A special serial adapter with power input is provided.

Data cable extensions: Vacuum compatible devices use the same mini-din cable extensions as our standard devices; however, the cable jacket is stripped back to the connectors to expose the individual wires. The mini-din connectors are left attached to facilitate easy testing. In your final application you can cut the wires and splice them to a feed-through on your vacuum chamber. Communication lines can be wired back to the appropriate mini-din connector outside your vacuum chamber. Power lines can be wired to any appropriate power supply. See the table below for pinouts. If you have multiple units inside the same vacuum chamber you may connect them using the attached mini-din connectors, or for improved vacuum compatibility you may remove the connectors and permanently wire the units together.

6. CONTROL THROUGH THE RS232 PORT

Your communications settings must be: 9600 baud, no hand shaking, 8 data bits, no parity, one stop bit. The amber LED will light when there is activity on the RS232 lines. You can use this feature to determine which COM port you are connected to. We recommend using the sample Visual Basic demo program included with Zaber products. It contains source code you can use as an example for writing your own programs.

Important: After power-up, the units in the chain will each initialize themselves as unit #1 and thus they will each execute the same instructions. To assign each unit a unique identifier you must issue a renumber instruction after all the units in the chain are powered up and every time you add or remove a unit from the chain. You must not transmit any instructions while the chain is renumbering or the renumbering routine may be corrupted. Renumbering takes less than a second, after which you may start issuing instructions over the RS232 connection.

All instructions consist of a group of 6 bytes. They must be transmitted with less than 10 ms between each byte. If the unit has received less than 6 bytes and then a period longer than 10 ms passes, it ignores the bytes already received. We recommended that your software behave similarly when receiving data from the devices, especially in a noisy environment like a pulsed laser lab.

The following table shows the instruction format:

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
Unit #	Command #	Data (least significant byte)	Data	Data	Data (most significant byte)

The first byte is the unit number in the chain. Unit number 1 is the closest unit to the computer and unit number 2 is next and so forth. If the number 0 is used, all the units in the chain will execute the accompanying command simultaneously.

The second byte is the command number. Bytes 3, 4, 5, and 6 are data in long integer, 2's complement format with the least significant byte transmitted first. How the data bytes are interpreted depends on the command. Complete details are given in the command reference on the following page.

Examples: Renumber all units: 0x00, 0x02, 0x00, 0x00, 0x00, 0x00
Home all units: 0x00, 0x01, 0x00, 0x00, 0x00, 0x00
Move unit #1 to an absolute position (command 20) of 257 micro-steps:
0x01, 0x14, 0x01, 0x01, 0x00, 0x00
Move unit #2 to a relative position (command 21) of -1 micro-step:
0x02, 0x15, 0xFF, 0xFF, 0xFF, 0xFF

If you are using Zaber's demo software, you will only see 3 entry fields: Unit#, Command#, and Data. The Unit# and Command# fields accept integer values while the Data field can be signed. The value in the data field is converted by the software to the 4 separate data bytes that get sent to the unit.

Most instructions cause the unit to reply with a return code. It is also a group of 6 bytes. The first byte is the device #. Byte #2 is the instruction just completed or 255 (0xFF) if an error occurs. Bytes 3,4,5 and 6 are data bytes in the same format as the instruction data byte.

7. COMMAND QUICK REFERENCE

The command quick reference below provides a list of available commands at a glance. A Detailed description of each command is given in the following section.

Command Quick Reference for Firmware version 2.93

Command	#	Data Bytes	Reply Data	Page
Reset	0	Ignored	None	12
Home	1	Ignored	Absolute position	12
Renumber	2	Ignored	Device ID	12
Move absolute	20	Absolute position	Absolute position	13
Move relative	21	Relative position	Absolute position	13
Move at constant speed	22	Speed setting	Echo of command data	13
Stop	23	Ignored	Absolute position	14
Restore default settings*	36	Ignored	Echo of command data	14
Set device mode*	40	Mode bits (see below)	Echo of command data	15
Set start speed*	41	Maximum step time setting	Echo of command data	16
Set target speed*	42	Target micro-step period	Echo of command data	16
Set acceleration*	43	Acceleration setting	Echo of command data	17
Set maximum travel range*	44	Range in micro-steps	Echo of command data	17
Set current position	45	New current position	Echo of command data	17
Set maximum relative move*	46	Maximum relative move	Echo of command data	18
Set alias*	48	Alias unit number	Echo of command data	18
Return device ID	50	Ignored	Device ID	18
Return firmware version	51	Ignored	Firmware Version	19
Return power supply voltage	52	Ignored	Power supply voltage	19
Return setting	53	Setting Number	Byte2: Setting number Byte3: Setting value	19
Return current position	60	Ignored	Absolute position	19

* The settings for these commands are saved in non-volatile memory, i.e. the setting persists even if the device is powered down. To restore all non-volatile settings to factory default values, use command 36.

Command #40, "Set mode" Options in Firmware version 2.93. See page 15 for details.

Data bits	Option Name	Effect
0 (1s)	Disable Auto-reply	Disables ALL replies except to commands 50 and higher
1 (2s)	Enable Anti-backlash	Enables the anti-backlash mode
2 (4s)	Enable Anti-sticktion	Enables the anti-sticktion mode
3 (8s)	Disable Potentiometer	Disables the potentiometer
4 (16s)	Enable Position Tracking	Enables position replies during constant speed commands
5 (32s)	Disable Manual Position Tracking	Disables automatic position replies during manual moves
6 (64s)	Enable Logical Channels Communications Mode	Enables the Logical Channels Communications Mode (see manual for more details)
7 (128s)	Home Status	Read-only. Cleared on power up. Gets set automatically when device homes or position is set with command #45.

Reply-Only Commands in Firmware version 2.93

Reply	#	Data Bytes	Reply Data	Page
Constant speed position tracking	8	N/A. Reply-only	Current absolute position	20
Manual move position tracking	10	N/A. Reply-only	Current absolute position	20
Power supply voltage out of range	14	N/A. Reply-only	Power supply voltage	20
Command data out of range	255	N/A. Reply-only	Current absolute position	20

8. DETAILED COMMAND REFERENCE

Note that these commands apply only to firmware versions 2.00 through 2.99. To determine which version of firmware you have simply issue the "return firmware version" command (51). Many of the commands described below will work with other firmware versions, however behavior may differ. See the appropriate user's manual for the version of firmware on your device.

8.1. *Reset (#0)*

Command Number:	0
Data Bytes:	Ignored
Reply Data:	None

Behavior:
This sets the device to its power-up condition. It has the same effect as unplugging and restarting the unit. The position stored in the device prior to this command will be lost, so you must save it and reload it if it is important.

8.2. *Home (#1)*

Command Number:	1
Data Bytes:	Ignored
Reply Data:	Absolute position (in this case 0)

Behavior:
The device retracts until it triggers its internal home switch. It then moves forward several steps to avoid accidentally triggering the home switch during use. It then stops and calls this position 0.

8.3. *Renumber (#2)*

Command Number:	2
Data Bytes:	Ignored
Reply Data:	Each unit replies with its device ID after renumbering.

Behavior:
This command must always be issued with a 0 in Byte 1 (i.e. it must be issued to all units simultaneously). If issued to a single unit, the command will be ignored. The unit closest to the computer becomes number 1. The next unit becomes 2 and so forth. Renumbering takes about 1/2 a second during which the computer must not send any further data. The unit number is not stored permanently, so the renumber command must be issued on each power-up.

8.4. *Move Absolute (#20)*

Command Number:	20
Data Bytes:	Absolute position in micro-steps.
Reply Data:	Absolute position after the move is finished. If the data is out of range the device will not move but will return 255 in byte 2.

Behavior:
The device moves to the position given by the data bytes. The position must be within the acceptable range for the device. Move commands are pre-emptive. In other words, if a new move command is issued before the previous move command is finished, the device will immediately move to the new position.

8.5. *Move Relative (#21)*

Command Number:	21
Data Bytes:	Relative position (can be negative) in micro-steps.
Reply Data:	Absolute position after the move is finished. If the data is out of range the device will not move but will return 255 in byte 2.

Behavior:
The device moves to the position given by its position before the command plus the value in the data bytes. The final position must be within the acceptable range for the device.

8.6. *Move at Constant Speed (#22)*

Command Number:	22
Data Bytes:	Velocity. Valid data are from -255 to +255 (negative values cause retraction, positive values cause extension). The velocity varies roughly from 0 to 40 steps/s for data from 0 to 63 and from 120 to 700 steps/s for data from 64 to 255.
Reply Data:	The reply is an echo of the command. The unit may also be set to return its position continuously during the move using the set mode command (#40) bit 4.

Behavior:
The unit moves at a constant speed determined by the data bytes until it receives a stop instruction or a new move instruction, or reaches a limit of travel. Speed is a non-linear, non-continuous function of the data with micro-stepping regions and full stepping regions. The velocity varies roughly from 0 to 40 steps/s for data from 0 to 63, and from 120 to 700 steps/s for data from 64 to 255. If precise speed control is important to your application, please contact Zaber for a table of exact speeds corresponding to all possible data.

8.7. *Stop (#23)*

Command Number:	23
Data Bytes:	Ignored.
Reply Data:	Current absolute position.

Behavior (version 2.59 and up):
The device will stop and return its current position.

Behavior (older versions):
In older versions this command functions only during a constant speed instruction. Issuing it during an absolute move or relative move will have no effect.

8.8. *Read/Write EEprom (#35)*

Command Number:	35
Data Bytes:	Byte 3 specifies the address and action to be performed (read or write). Byte 4 specifies the data to write (it is ignored for reads). Bytes 5 and 6 are ignored.
Reply Data:	The reply data is simply an echo of the command data except that byte 4 contains the data read from the specified address

Behavior (version 2.53 and up):
This command is used to read or write a byte of non-volatile memory. 128 bytes of EEPROM memory are available for user data. For example, the user may want to load some custom data such as a serial number, a name string, or data that uniquely identifies a particular actuator. Data written is not cleared by power down or reset. The most significant bit of byte 3 specifies whether the instruction is a read (0) or a write (1). The least significant 7 bits of byte 3 specify the address to read/write (0 to 127). Byte 4 specifies the data to write (it is ignored for reads).

Behavior (older versions):
Not implemented.

8.9. *Restore factory default settings (#36)*

Command Number:	36
Data Bytes:	Ignored. Settings saved in EEPROM (Non-volatile)
Reply Data:	Reply data is simply an echo of the command data

Behavior (version 2.59 and up):
This command changes all settings back to their factory default values. Settings are stored in non-volatile memory and thus are unaffected by power down.

Behavior (older versions):
This instruction is not available in versions older than 2.59. Instead settings are stored in volatile memory and thus are reset to factory defaults on every power down or reset.

8.10. *Set Device Mode (#40)*

Command Number:	40
Data Bytes:	Bytes 3 and 4 are the mode configuration bytes. All other bytes are ignored.
Reply Data:	Reply data is simply an echo of the command data

Behavior (version 2.77 and up):
This command allows setting several options. Each option is controlled by a single bit within Bytes 3 and 4. All settings are stored in non-volatile memory and are not affected by power down or reset.

Byte 3 bit	Description
0 (1s)	Disable Auto-reply A value of 1 disables ALL replies except those to "return" commands (commands 50 and higher). The default value is 0 on all devices.
1 (2s)	Enable Anti-backlash Routine A value of 1 enables the anti-backlash routine. On negative moves (retracting), the device will overshoot the desired position by 10 steps, reverse direction and approach the requested position from below. On positive moves (extending), the device behaves normally. Care must be taken not to crash the moving payload into a fixed object due to the 10 step overshoot on negative moves. The default value is 0 on all devices.
2 (4s)	Enable Anti-sticktion Routine A value of 1 enables the anti-sticktion routine. On moves less than 10 steps, the device will first retract to a position 10 steps less than the requested position and approach the requested position from below. Care must be taken not to crash the moving payload into a fixed object due to the 10 step negative move. The default value is 0 on all devices.
3 (8s)	Disable Potentiometer A value of 1 disables the potentiometer preventing manual adjustment of the device. The default value is 0 on all devices.
4 (16s)	Enable Constant Speed Position Tracking A value of 1 enables position tracking during constant speed commands. The unit will return its position periodically when a constant speed command is executed. The Disable Auto-Reply option above takes precedence over this option. This feature is available in firmware versions 2.04 and higher. The default value is 0 on all devices.
5 (32s)	Disable Manual Position Tracking A value of 1 disables automatic position replies during manual moves. The Disable Auto-Reply option above takes precedence over this option. This feature is only available in firmware versions 2.09 and higher. The default value is 0 on all devices.
6 (64s)	Enable Logical Channels Mode A value of 1 enables the Logical Channels Mode. In this mode of communication, only bytes 3 thru 5 are used for data. Byte 6 is used as an ID byte that the user can set to any value they wish. It will be returned unchanged in the reply. Logical Channels Mode allows the user application to monitor communication packets individually to implement error detection and recovery. The default value is 0 on all devices.
7 (128s)	Home Status This bit is cleared automatically on power-up or reset. It is set automatically when the device is homed or when the position is set using command #45. It can be used to detect if a unit has a valid position reference. It can also be set or cleared by the user.

<table>
<tr><td>8 (256s)
9 (512s)</td><td>Set Hold Current
Stepper motors have a detent torque that causes the motor to jog to the nearest full step position when no current is applied. On T-LA, T-LS, and T-MM series devices, the leadscrew friction is higher than the detent torque, and the hold current may be set to zero without losing position due to this jogging effect. On other devices, however, the hold current should be turned on unless the apparatus to which the device is connected provides sufficient additional friction to hold the micro-step position.

Bits 8 and 9 are used together for this purpose:

<table>
<tr><td>Bit 8</td><td>0</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>Bit 9</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>Hold Current</td><td>0%</td><td>50%</td><td>75%</td><td>100%</td></tr>
</table>

The default values of bits 8/9 are 0/0.</td></tr>
</table>

Behavior (older versions):
In earlier versions, only bits 0 through 6 are implemented. The hold current is always 0.

8.11. *Set Start Speed (#41)*

Command Number:	41
Data Bytes:	Byte 3 is the starting step period (time to move 1 full step) in increments of roughly 0.05us. The default is 96 (4.8ms). Other data bytes are ignored.
Reply Data:	Reply data is simply an echo of the command data

Behavior:
Data represents the starting step period in units of roughly 0.05 us. Valid data are from 1 to 255. In practice, data less than about 25 is likely to cause stalling. The starting step period must be greater than the target step period (set with command number 42).

8.12. *Set Target Speed (#42)*

Command Number:	42
Data Bytes:	Byte 3 is the target step period (time to move 1 full step) in increments of approximately 0.05 ms. The default is 48 (2.4ms) Other data bytes are ignored.
Reply Data:	Reply data is simply an echo of the command data

Behavior:
When the device moves, it starts at an initial speed determined by the “Start Speed” setting, and accelerates at the acceleration rate up to a maximum speed determined by the “Target Speed” setting. These settings are recorded as step periods (the smaller the period, the faster the speed). Note that step periods less than 1.5ms are likely to result in missed steps or stalling even with no load since torque decreases with speed.

8.13. *Set Acceleration (#43)*

Command Number:	43
Data Bytes:	Byte 3 is the acceleration rate in increments of about 0.05 ms per step per step. The default is 1 (0.05 ms/step/step). Valid data are from 1 to 255. Other data bytes are ignored.
Reply Data:	Reply data is simply an echo of the command data

Behavior:
The acceleration setting specifies the amount of time subtracted from the step period after each full step when accelerating from the starting speed up to the target speed. The default value of 1 (0.05ms) corresponds to the slowest available acceleration and is generally sufficient. If faster acceleration is desired, try increasing the value.

8.14. *Set Range (#44)*

Command Number:	44
Data Bytes:	The desired new range in micro-steps. The least significant byte is rounded up to 0xFF. The true range will be within 4 steps of the specified value
Reply Data:	Reply data is simply an echo of the command data

Behavior (version 2.09 and up):
Use this command to limit the range of travel to a value other than the default. Exercise caution since using this command it is possible to set the range to a value greater than the physical limits of the device.

Behavior (older versions):
Not implemented. The range is fixed for a given device and cannot be changed by the user.

8.15. *Set Current Position (#45)*

Command Number:	45
Data Bytes:	Absolute position.
Reply Data:	Absolute position (in this case the position that was just set).

Behavior:
The internal register that holds the position is set to the value given by the data bytes. The phase of the stepper motor is controlled by the least significant byte of the position, thus the device may move by +/- 2 full steps unless the new position has the same phase. This command is useful if you want to turn off the system without losing position. Simply save the position in the controlling computer before powering down. After powering up, set the position back to the saved value. In this way you can continue without having to home the device.

8.16. *Set Maximum Relative Move (#46)*

Command Number:	46
Data Bytes:	The desired maximum relative move in micro-steps Setting saved in EEPROM (Non-volatile)
Reply Data:	Reply data is simply an echo of the command data.

Behavior (versions 2.58 and up):
Use this command to limit the maximum range of travel for a relative move command. For example, if maximum relative move is set to 1000, and the user requests a relative move (#20) of 800, then the device will move 800 microsteps. However, if the user requests a relative move of 1200, then the device will reply with an error (#255). Most applications can leave this unchanged from the default.

Behavior (older versions):
Not implemented.

8.17. *Set Alias (#48)*

Command Number:	48
Data Bytes:	Byte 3 is the alias unit number. Valid numbers are between 0 and 254. To avoid confusion, it is best to choose an alias greater than the number of units connected. However this is not required.
Reply Data:	Reply data is simply an echo of the command data.

Behavior (versions 2.52 and up):
This creates an alternate unit number for a device (in addition to its actual unit number). By setting several units' aliases to the same value, you can control groups of units with a single instruction. When you send an instruction using an alias unit number, all devices with that alias will execute the instruction and reply using their actual unit numbers. To remove an alias, simply set it to zero, or reset all settings to factory defaults.

Behavior (older versions):
Not implemented.

8.18. *Return Device ID (#50)*

Command Number:	50
Data Bytes:	Ignored.
Reply Data:	Device ID.

Behavior:
This causes the unit to return an identification code indicating the type of device connected.

8.19. *Return Firmware Version (#51)*

Command Number:	51
Data Bytes:	Ignored.
Reply Data:	Firmware Version. Note that the firmware version may take up more than one byte.

Behavior:
This causes the unit to return its firmware version number. A decimal is assumed before the last two digits. For example, reply data of 0x000000FD = 253 = firmware version 2.53.

8.20. *Return Power Supply Voltage (#52)*

Command Number:	52
Data Bytes:	Ignored.
Reply Data:	Power supply voltage.

Behavior:
This causes the unit to return the voltage of its power source in increments of 0.1 Volts. (Ex. 127 indicates 12.7 V).

8.21. *Return Setting (#53)*

Command Number:	53
Data Bytes:	Setting Number
Reply Data:	Setting number in Byte2. Setting value in data bytes.

Behavior:
This causes the unit to return the current value of the setting number (40 through 48) specified in Byte3. The unit will reply with the setting number in Byte2, as if a command to change the setting had just been issued but the setting will not be changed.

8.22. *Return Current Position (#60)*

Command Number:	60
Data Bytes:	Ignored.
Reply Data:	Current absolute position.

Behavior (all versions):
This causes the unit to return its current micro-step position.

9. REPLY-ONLY COMMAND REFERENCE

In general, a T-series device will reply to an instruction using the same command number as the instruction itself. However, there are occasions (such as when the user turns the potentiometer) when the device may transmit data without first receiving a request from the controlling computer. This type of reply may be considered to be a triggered reply as opposed to a requested reply. In this case the device uses a "reply-only" command number to distinguish the reply from those requested by the controlling computer. The meanings of these replies and their corresponding data are given below.

9.1. *Reply #8 –Position tracking during constant speed move*

Reply Command Number:	8
Reply Data:	Current absolute position in microsteps

Meaning:
The unit has been set to position tracking mode (see Set Mode instruction) and given a constant speed instruction. In this mode, the unit sends a reply with command #8 at regular intervals updating the current position during constant speed instructions.

9.2. *Reply #10 – Position tracking during manual move*

Reply Command Number:	10
Reply Data:	Current absolute position in microsteps

Meaning:
The unit has been moved manually (the knob is turned). If enabled with the Set Mode instruction, the unit sends this reply at regular intervals updating the current position during manual moves.

9.3. *Reply #14 – Power supply voltage out of range*

Reply Command Number:	14
Reply Data:	Measured power supply voltage in increments of 0.1V (i.e. 97 = 9.7V)

Meaning:
This reply is triggered when the power supply voltage moves out of range. If your power supply is not capable of enough current to drive the devices connected to it, you may see this reply. You will also see it if the power supply voltage is too high.

9.4. *Reply #255 – Error*

Reply Command Number:	255
Reply Data:	Current position in microsteps

Meaning:
This reply indicates that the command data is out of range.

10. DEVICE SPECIFIC INFORMATION

Zaber T-Series positioning devices are driven by stepper motors using a micro-stepping controller with 64 micro-steps per step. All position data sent to or received from Zaber T-Series devices must be in units of micro-steps (your software must convert position data entered by the user to micro-steps before sending it to your device). The linear or angular displacement corresponding to a single micro-step of travel depends on the device. The following section gives this and other information specific to each T-Series product.

10.1. *T-HLA Series – Heavy duty linear actuators*

T-HLA - Heavy duty Linear Actuator

Motor:	96 steps/revolution
Device motion:	609.6 um/revolution
Default settings:	Mode: 0
	Start Speed: 96
	Target speed: 48

10.2. *T-LA Series – Linear actuators*

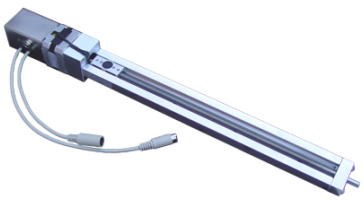
T-LA - Precision Linear Actuator

Motor:	48 steps/revolution
Device motion:	304.8 um/revolution
Default settings:	Mode: 0
	Start Speed: 96
	Target speed: 48

10.3. *T-LLS Series – Long travel linear slides*

T-LLS - Long travel Linear Slide

Motor:	200 steps/revolution
Device motion:	2 mm/revolution
Default settings:	Mode: 0
	Start Speed: 96
	Target speed: 48



10.4. *T-LS – Linear stages*

T-LSxx - Linear Stage

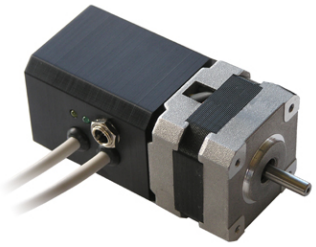
Motor:	48 steps/revolution
Device motion:	304.8 um/revolution 6.35 um/step
Default settings:	Mode: 0 Start Speed: 96 Target speed: 48

T-LS linear stages contain a spring which applies a light load against the leadscrew. Typically these stages are used in a horizontal orientation, and the only force experienced by the leadscrew is the spring force, which serves to keep the load on the leadscrew always in the same direction, thus reducing backlash. If used in a vertical orientation, the spring is not needed to reduce backlash since the load (the weight of the stage and whatever may be mounted to it) is always in the same direction by default. In fact, if the load is greater than the minimum spring force and less than the maximum spring force, the existence of the spring will actually introduce backlash since there will be a point in the stage travel where the load on the leadscrew changes direction. Therefore, when using T-LS stages in a vertical orientation, we recommend removing the spring from the stage. This can be done relatively easily using a small hook fashioned from a paperclip to slip the spring off its mounting posts and slide it out of the stage. It may help to fully extended the stage prior to spring removal.

10.5. *T-NM – NEMA stepper motors with built in controllers*

T-NM - NEMA 17 Stepper Motor with controller

Motor:	200 steps/revolution
Device motion:	1.8°/step
Default settings:	Mode: 0 Start Speed: 96 Target speed: 48



Most Zaber positioning products have built-in home sensors. However, on the T-NM series of devices, the home sensor is optional. Depending on the user's application, the home sensor may or may not be required. Therefore, the home sensor on these devices is removable (note: this may not be the case on some older models).

The purpose of the home sensor is to set a reference or zero position to "sync" the controller position to the actual device position. On power-up, the default reference position assumed by the controller is typically the maximum range setting. In certain applications (for example continuous rotation at controlled velocities), position synchronization isn't required, and the home sensor may not need to be installed.

If you choose not to install the home sensor, then DO NOT ISSUE A HOME INSTRUCTION (command #1). If you do, the motor will reverse indefinitely waiting for the non-existent home senor to be triggered. Instead you can set the initial position using the Set Current Position instruction (command #45).

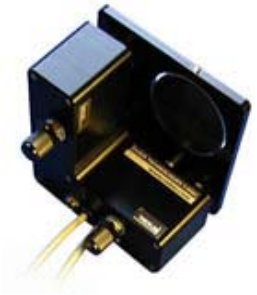
The home sensor consists of a hall switch connected to a cable which plugs into the motion control device. A small magnet (included) activates the home sensor when it approaches within about 0.5mm of the face of the hall switch. If you choose to install the home sensor, you must mount the hall switch and magnet in the orientation shown. Experiment to determine the correct way around for the magnet as it will only work in one orientation. Simply issue the home command, and move the magnet in front of the hall switch as shown in the image below, if the motor does not stop, turn the magnet around and try again. Typically the easiest way to install the hall switch and magnet is to glue them in place as shown in the image below. Be sure that the hall switch is mounted to a fixed part, and the magnet to a moving part, and that negative motion of the motor (ex a negative relative move, negative constant speed move, or counterclockwise turn of the manual control knob) brings the magnet closer to the hall sensor.

Home Sensor Installation

10.6. *T-MM2 – 2 axis motorized mirror mounts*

T-MM2 - Motorized mirror mounts

Motor:	48 steps/revolution
Device motion:	304.8 um/revolution 6.35 um/step
Default settings:	Mode: 0 Start Speed: 96 Target speed: 48



T-MM2 devices contain two actuators, each of which behaves as an independent unit in the Chain. Therefore, even if you have only one T-MM2 device connected to your computer, you must issue the renumber instruction before you will be able to control each axis independently.

Zaber positioning products generally accept only positive position data ranging from 0 up to the maximum range of the device. The T-MM2, however, can accept negative position data. This simplifies the calculations required to convert from linear to angular dimensions. Acceptable positions for the T-MM2 axis actuators are in the range from –65536 micro-steps (the home or fully retracted position) to +60671 micro-steps (the maximum extended position). A linear position of zero micro-steps corresponds to an angular position of zero micro-radians (urad). In this position, the plane of the moveable plate on which the optics are mounted should be approximately parallel to the front face of the mirror mount housing. The distance l from the actuator contact points to the pivot point is 66.66 mm. Using the approximation $d\Phi = \frac{dp}{l}$ where dp is linear displacement of the actuator and $d\Phi$ is angular displacement of the mounting plate yields an angular resolution of 15 urad per um of linear travel. This approximation is good for positions near zero but introduces an error up to 300 urad at the minimum and maximum travel. If better accuracy is desired over the full range of motion then the equation $\tan\left(\frac{\Phi}{1000}\right) = 0.09921875 \cdot \frac{p}{l}$ should be used where p is the actuator position in micro-steps, l is 66660 um, and Φ is the desired angular position in mrad. The following table was created using the above calculations.

T-MM2 Position Table – Dimensional Cross-Reference

Actuator extension [micro-steps]	Actuator extension [um]	mrad (using 15 urad/um approximation)	mrad (using tangent equation)
-65536 (min / home)	-6502.4	-97.536	-97.238
0	0	0	0
+60671 (max)	+6019.7	+90.296	+90.060

11. MANUAL CONTROL AND LED INDICATORS

Turning the potentiometer knob (on units so equipped) will make the device move. It is not necessary to have a computer connected to use the device in manual mode. However, without a computer connected you have no means to initialize the device with a starting position. Therefore you must retract it completely after each power up in order to home the device. You will not be able to extend it fully until you have first retracted it completely to set the home position. Clockwise rotation of the knob produces positive motion (extension) and counter clockwise rotation produces negative motion (retraction). The speed of retraction or extension will be directly related to the amount to which the knob is turned from its center detent position (turning the knob to its center position will stop the unit from moving). During manual moves, the unit constantly returns its position so a computer can track the position even when you are controlling the unit manually. Manual control can be disabled with a mode setting.

During operation if the plunger is extended or retracted against a force greater than its thrust capability the unit will stall and there will be “missed steps”. This can result in an apparent malfunction in that the device believes its position to be other than it actually is and will not extend or retract the plunger past a given position. Without connecting a computer to home the device or set its position, the only solution is to retract the plunger until it activates the internal home switch, which will automatically zero the device at the home position. A problem arises if the device incorrectly believes its position to be zero since it will not retract to the home position. In this case you must disconnect and reconnect the power before manually homing the device.

The green LED is on whenever there is power to the device. The amber LED flashes when there is traffic on the RS232 line. It also stays on while the device is moving. A constant blinking of the amber LED indicates that the power supply voltage is out of range.

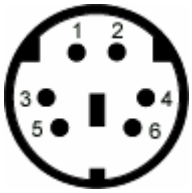
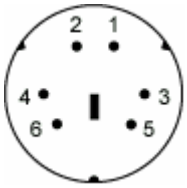
12. TROUBLESHOOTING

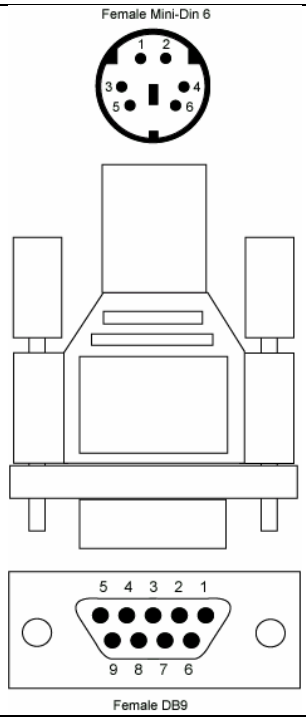
Symptom	Check
The unit is not communication or responding to computer control. The yellow LED may be dimly lit.	If the actuator has a manual control knob, make sure the knob is centered. Turn it back and forth until you feel a click or detent. Leave the knob at the center detent position. Then turn unit off and on, and try again.
The unit is moving very slowly. It used to behave differently.	Make sure that the unit's settings have been restored to factory default. The speed settings may have been changed inadvertently. The easiest way is to use command 36 to restore all settings to factory default.
Green LED does not come on	Check the A/C wall plug, the 12 V adapter and its connection to the device. If the power is coming over the data cable, check the mini din connector for bent or broken pins.
Unit starts moving as soon as the power is on or amber LED stays on all the time	The potentiometer is probably not centered. Turn the knob slowly until you feel the center detent. The amber light should turn off.
Amber light flashes	The power supply voltage is outside the range of 10 to 16V. It may either be too low or too high. Some unregulated 12 V adapters may produce in excess of 16 V. If the number of devices connected on a single 12 V adapter exceeds its current capability, the voltage may drop below 10 V. You may experience this problem when many motors on a single supply move together. The load may exceed the maximum current available, causing the voltage to drop too low. If you experience this problem with a single device on an unregulated 12V supply rated at over 300 mA, then the problem is likely that the supply voltage is too high.
Turning the potentiometer causes no motion	You may be at the end of travel. This can happen due to missed steps even if the device does not appear to be fully extended. Turn the knob the other way. If the unit makes noise but does not move you may be in a stall condition (especially if the device appears to be fully extended). See "Stall Condition" below. The amber light should come on when turning the knob, if not, try turning the power off and then on again. If the unit does not make any noise even when turning the knob both ways, the green light is on and the amber light does not flash but turns on when turning the knob or stays off all the time, the unit needs servicing.
Communications do not seem to work, the amber light does not come on or flash	Make sure that you are on the correct com port. Check the baud rate, hand shaking, parity, stop bit, etc. Check the cable and adapter for bent or broken pins. Make sure you do not have a null modem adapter or cable in the line. The serial to mini-din adapter comes in many varieties and many have different pin connections. Check the adapter for continuity on the proper pins by consulting the adapter pin-out diagram below. If you encounter the problem when trying to control the device with your own software, try using one of the demo programs from our website to verify that the hardware is functioning properly.
The amber light comes on briefly when sending a command, but the device does not move and does not return codes.	Check baud rate, hand shaking, parity, stop bit, etc. Make sure that your software does not transmit any control characters like line feed, spaces or something else. The numbering software may have been corrupted and the unit numbers may not be what you think they are. Issue a renumber command, make sure that the computer does not transmit anything else while the units renumber. Check that you transmit 6 bytes and that the unit number and command are valid. If you encounter the problem when trying to control the device with your own software, try using one of the demo programs from our website to verify that the hardware is functioning properly. If the unit makes noise but does not move, you may have a stall condition, see below.

The unit does not send replies but otherwise works.	If you encounter the problem when trying to control the device with your own software, try using a demo program from our website to verify that the hardware is functioning properly. Make sure that the receiving part of your code or commercial package is correct. Check baud rate, etc. Check connectors for bent or broken pins.
The unit sometimes returns fewer than 6 bytes.	This problem usually indicates a problem with the settings for your serial port. Some serial ports are set to automatically recognize and remove specific control characters such as carriage returns when they appear in the RS232 receive buffer. When this happens, it appears as though the device has not sent enough bytes, but really the controlling computer has just removed some before you could read them. You will need to change the serial port settings to fix the problem.
Stall condition: The unit makes noise but does not move.	Try removing all external loads. If the unit now extends and retracts normally, the problem is excessive load. Try to reduce the load or change step time and acceleration parameters to ensure the load is less than the maximum thrust. If the unit is stalled in its fully extended position and remains stalled without any external load applied it means the lead screw has been over extended and is stuck. You can usually get the lead screw unstuck by pushing on it after issuing the home command. If the unit is stalled (with no external load) in a position that is not fully extended then it requires servicing.
Poor repeatability or the unit does not extend or retract smoothly or makes louder than normal noise during travel.	You may be skipping steps. When skipping, the unit will loose position in increments of 4 steps, that is in multiples of 25.4 um. This condition happens if the thrust needed is more than the thrust available from the device. Check that the force on the device is less then the maximum thrust. Check the voltage using the voltage command. Voltage less then 12 V will reduce the unit's maximum thrust. Be very careful when changing minimum step time, maximum step time and acceleration. A bad choice can introduce skipping. Lead screw conditions greatly affect the performance of the unit. Dirt, damaged threads, no grease or too heavy grease will degrade performance and may contribute to a stall. A black residue appears on the lead screw after extended use. This can increase friction and reduce trust. Clean the screw and re-grease it. In general if you try to move a large payload or have a large static axial load (like lifting something vertically) you will have more problems. For vertical motion the use of a counterweight, spring or rubber band can help reduce the static load and improve the performance of the device. The default value of the acceleration, max step time and min step time are good for small to medium loads and medium speeds. For very light loads and higher speeds, or heavy loads at lower speeds, these parameters can be tuned. Trial and error is the best tuning technique!!
The device extends and retracts smoothly but will not retract to the home (zero) position.	The device will not retract below what it believes to be the zero position. If the unit has missed steps due to a previous stall condition or if the unit has been set to an incorrect position, the device may incorrectly believe it is at the zero position. You can solve the problem by issuing the home command, or by turning the unit on and off and manually homing it.

13. DATA CABLE PINOUT DIAGRAM

The tables below show the pin-outs of communications connections on the device and on the serial adapter.

Device Pin Configuration		
	Female PS2 Pin-outs (Towards next unit) 	Male PS2 Pin-outs (Towards computer) 
1	Not connected	Not connected
2	Receive (from next unit)	Transmit (toward computer)
3	Ground	Ground
4	+12V Power	+12V Power
5	Not Connected	Not Connected
6	Transmit (to next unit)	Receive (from computer)

Serial Adapter Pin Configuration			
	Min-Din 6	DB9	Function
	2	2	Device Transmit, Computer Receive
	3	5	Ground
	6	3	Device Receive, Computer Transmit
	All Others		Not Connected

14. WARRANTY

All Zaber products are backed by a one-month satisfaction guarantee. If for any reason you are not satisfied with your purchase, send it back to Zaber Technologies Inc. within one month of the purchase date for a complete refund.

T-series devices are also guaranteed for one year or 50,000 cycles, whichever comes first. During this period Zaber will repair or replace faulty units free of charge. Customers are responsible for shipment back to Zaber.

For complete details of our warranty and other policies please see our website.

15. REPAIRS

If your unit needs repairs, please:
Contact us to obtain an RMA number.
On units with exposed leadscrews (i.e. T-LA series), if possible, retract the lead screw fully into the housing. This way the lead screw is protected from damage during shipping.
Pack the unit well.
Email us the tracking number of the shipment (i.e. FedEx or UPS)

16. EMAIL UPDATES

If you would like to receive our quarterly email newsletter with product updates and promotions, please sign up online at http://www.zaber.com (news section).

17. DISCLAIMER

Zaber's devices are not intended for use in any critical medical, aviation, or military applications or situations where product malfunction or failure could cause personal injury or death, or damage to equipment. Zaber disclaims any and all liability for injury or other damages resulting from the use of its products.

18. TECHNICAL SUPPORT AND CONTACT

You can contact Zaber Technologies Inc. for technical assistance by on one of the following methods:

Phone:	1-604-276-8033 (direct) 1-888-276-8033 (toll free in North America)
Fax:	604-648-8033
Mail:	2891 Steveston Hwy, Richmond, BC, Canada, V7E 2J1
Web:	http://www.zaber.com (for up to date information on all Zaber products)
Email:	Please visit our website for up to date email contact information.

APPENDIX A – FACTORY DEFAULT SETTINGS

The following tables show the default settings for all Zaber T-Series devices under firmware version 2.93. To reset a device to its default settings, simply issue command #36. Note that all firmware versions prior to 2.59 store settings in volatile memory and therefore settings are reset every time the device is powered down.

Default settings in firmware version 2.93

(note that in 2.93 firmware the Microstep Resolution is fixed at 64 microsteps/step)

Product prefix	Mo tor [V]	Motor Steps / Rev	Screw Pitch [um/step]	Device ID	Range [micro-steps]	Powerup Position	Start Speed	Target Speed	Accel-eration	Mode
T-HLA28	12	96	6.35	228	282879	Range	96	48	1	0
T-LA13 or T-LS13	12	48	6.35	13	131327	Range	96	48	1	0
T-LA28 or T-LS28	12	48	6.35	28	282879	Range	96	48	1	0
T-LA60	12	48	6.35	60	606463	Range	96	48	1	0
T-LS80	12	48	6.35	80	806399	Range	96	48	1	0
T-LLS105	12	200	10	701	672255	Range	96	48	1	0
T-LLS260	12	200	10	702	1664255	Range	96	48	1	0
T-MM2 *	12	48	6.35	302	126207	Range *	96	48	1	0
T-NM	12	200	n/a	600	606463	Range/2	96	48	1	0

* The T-MM2 product has a home position of -65536 instead of 0. Since the default range is 126207, the default maximum position is –65536 + 126207 = 60671.